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(54) **Twisted Nematic Field Effect Mode Liquid Crystal Display Cell Structure**

(57) A twisted nematic field effect mode liquid crystal display cell comprises a liquid crystal layer 7 sandwiched between front and rear substrates 4, 11 on which transparent electrodes 5, 10 are formed, a front polarizer 3 disposed in front of the front substrate, and a rear polarizer 12 disposed at the back of the rear substrate. The rear substrate 11 comprises a glass plate, and the front substrate 4 comprises a fiber-optic plate to reduce the dependence of contrast on azimuthal viewing angle. Substantially in register and coextensive with each picture element of the cell, as determined by the electrodes 5, 10, is the end of a fibre core, or group of fibre cores, whereby the display contrast, is not degraded by the presence of plate 4.

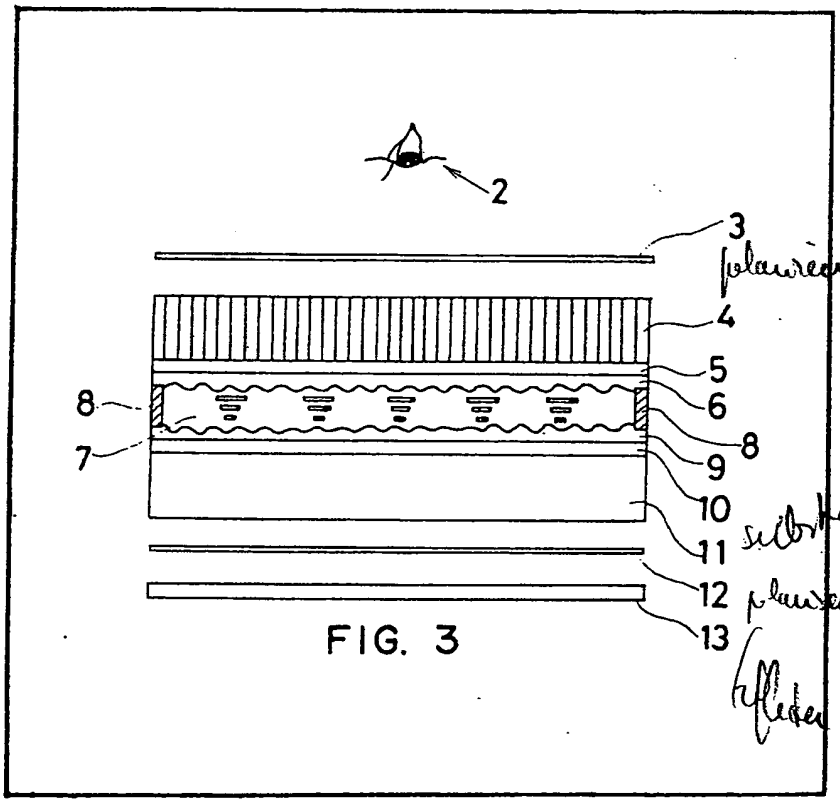

FIG. 3

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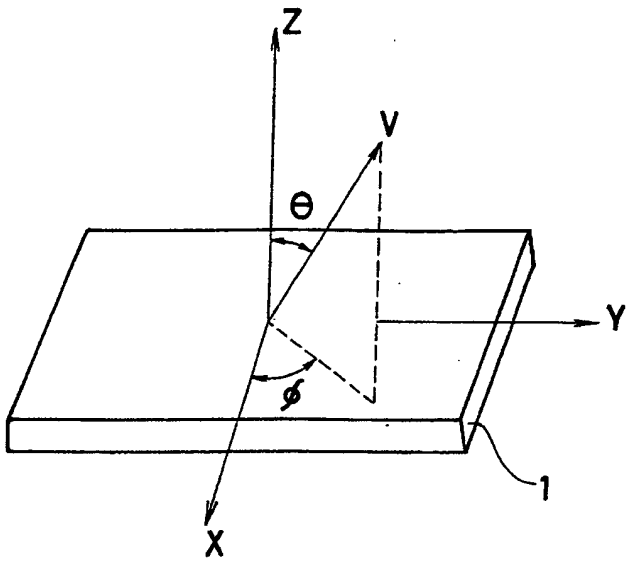

FIG. 1

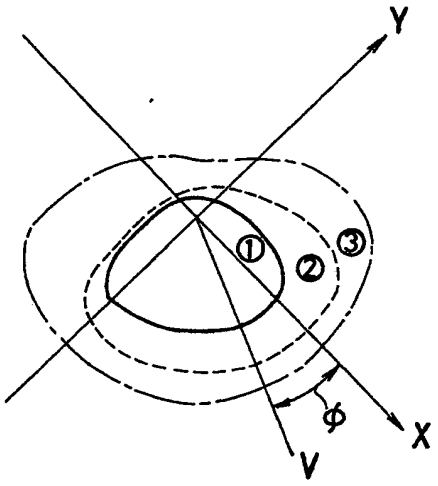

FIG. 2

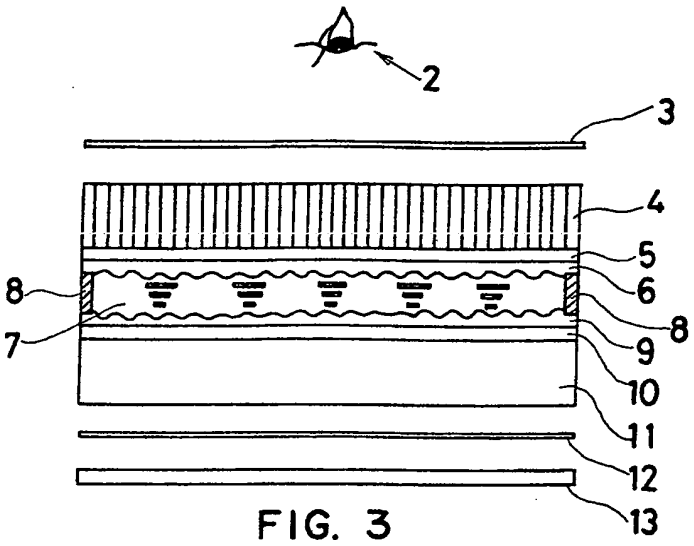

FIG. 3

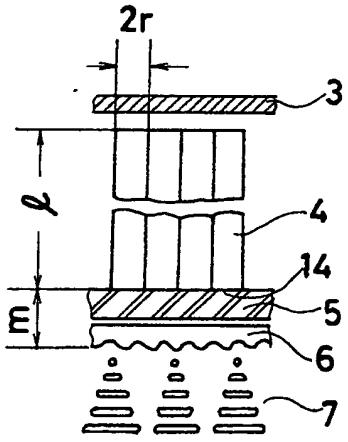

FIG. 4

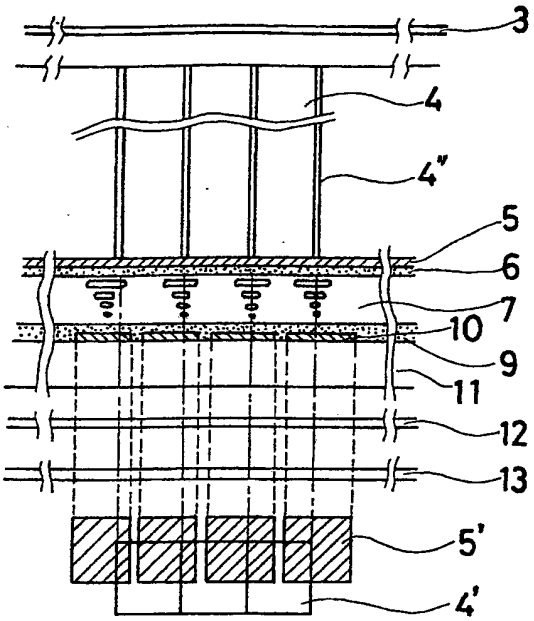

FIG. 5

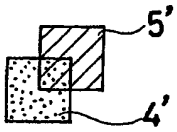

FIG. 6(A)

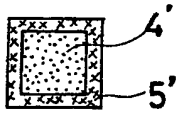

FIG. 6(B)

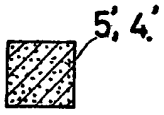

FIG. 7(A)

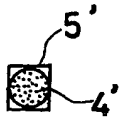

FIG. 7(B)

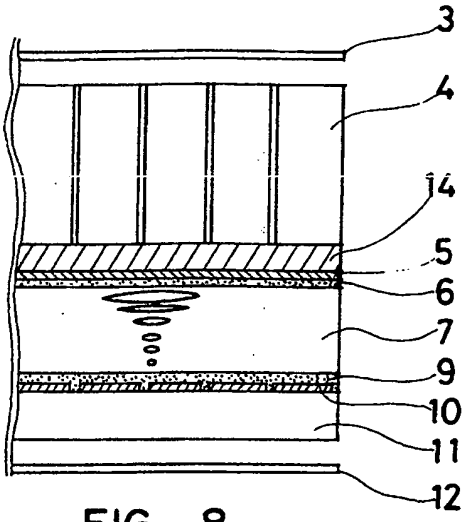

FIG. 8

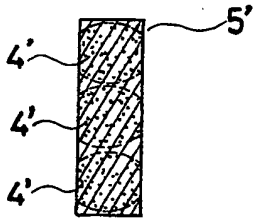

FIG. 9

SPECIFICATION

Twisted Nematic Field Effect Mode Liquid Crystal Display Cell Structure

Background and Summary of the Invention

The present invention relates to a twisted nematic field effect mode liquid crystal display and, more particularly, to a cell structure which improves viewing angle characteristics.

Generally, the twisted nematic field effect mode liquid crystal display exhibits a peculiar viewing angle dependent property beacuse of the twisted construction of liquid crystal molecules. The viewing angle range varies in a fashion depending on a driving voltage level applied to the liquid crystal display cell. A remarkable viewing angle dependency is observed when the display is driven by a signal of a low effective voltage.

Accordingly, an object of the present invention is to provide a twisted nematic field effect mode liquid crystal display cell, which enhances the display quality.

Another object of the present invention is to uniform the display contrast without regard to a viewing angle in a twisted nematic field effect mode liquid crystal display.

Still another object of the present invention is to enhance the display contrast and the brightness in a twisted nematic field effect mode liquid crystal display.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

To achieve the above objects, pursuant to an embodiment of the present invention, a front substrate for sandwiching a liquid crystal layer comprises a fiber plate. The fiber plate is made of a plurality of optical fibers of which axes are perpendicular to the liquid crystal layer. The fiber plate has a surface confronting the liquid crystal layer and substantially parallel to the liquid crystal layer. Each optical fiber has an open end of a shape substantially corresponding to a display picture element configuration.

Brief Description of the Drawings

The present invention will be better understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus ar not limitative of th present inventi n and wherein:

Figure 1 is a p rspective view for explaining a viewing angle;

Figure 2 is a schematic chart for explaining an observing direction dependency in a twisted nematic field effect m de liquid crystal display of the prior art;

Figure 3 is a schematic sectional view of a basic structure of a twisted nematic field effect mode liquid crystal display cell of the present invention;

Figures 4 and 5 are enlarged sectional views of a portion of the twisted nematic field effect mode liquid crystal display cell of Figure 3;

Figures 6(A) and 6(B) are schematic plan views showing relative positions of the picture element and the optical fiber in the conventional cell;

Figures 7(A) and 7(B) are schematic plan views showing relative positions of the picture element and the optical fiber in an embodiment of the present invention;

Figure 8 is an enlarged sectional view of a portion of an embodiment of a twisted nematic field effect mode liquid crystal display cell of the present invention; and

Figure 9 is a schematic plan view showing a relative position of the picture element and the optical fibers in another embodiment of the present invention.

Description of the Preferred Embodiments

Referrring now in detail to the drawings, and to facilitate a more complete understanding of the present invention, observing direction factors θ and ϕ are first defined with reference to Figure 1.

XY rectangular coordinates determine a display surface of a liquid crystal display device 1 in such a manner that the X axis parallels a major axis of liquid crystal molecules adjacent to one substrate in a condition where no electric field is applied to the device. A Z axis determines the normal direction of the display surface. An angle θ represents an angle formed between an observing direction vector V and the Z axis, and an angle ϕ represents an angle formed between the X axis and a projection of the observing vector V on the XY coordinates plane.

Figure 2 shows an observing direction dependency in a twisted nematic field effect mode liquid crystal display of the prior art.

Figure 2 shows a display contrast ratio varying in dependent on the angle ϕ, when the angle θ is constant (θ=20°), wherein a curve ① shows a condition where the effective value of the applied voltage is 2.5 volts, a curve ② shows a condition where the effective value is 3.0 volts, and a curve ③ shows a condition where the effective value is 6.0 volts. More specifically, the area surrounded by the curve exhibits a good display contrast, whereas the exterior of the curve does not exhibit the good contrast.

It will be clear from Figure 2 that the viewing angle range is narrowed as the applied voltage becomes low. Moreover, the good contrast is obtained in a certain direction on the XY coordinates plate.

The detection of the property shown in Figure 2 was c nducted in the following condition.

The liquid crystal composition comprises the Schiff base mixture liquid crystal f MBBA, EBBA and BBAB, the liquid crystal layer has th 6μm

thickness, the tilted angle of the liquid crystal molecules on the substrate is below 5° under the condition where no electric field is applied thereto, the electrode comprises the In_2O_3 transparent electrode, the orientation layer comprises the SiO_2 layer having grooves formed through the rubbing method, and the drive voltage comprises a rectangular alternating voltage signal of 32 Hz.

The ϕ dependency of the display contrast becomes large when the twisted nematic field effect mode liquid crystal display is driven in the multiplex fashion, or, the dynamic fashion. This is because the effective voltage level is reduced as the multiplex ratio increases.

To minimize the above-mentioned defects, it is proposed to form a front substrate of the twisted nematic field effect mode liquid crystal display cell with a fiber plate. The fiber plate is made of a plurality of optical fibers of which axes are perpendicular to the liquid crystal layer. The fiber plate has a surface confronting the liquid crystal layer and substantially parallel to the liquid crystal layer. And a front polarizer is disposed in front of the fiber plate. A typical construction of the twisted nematic field effect mode liquid crystal display cell including the fiber plate is described in our published copending U.K. Patent Application No. 784212 (Publication No. 2010517).

Figure 3 schematically shows the twisted nematic field effect mode liquid crystal display cell proposed in that application; the basic structure of this cell can also be used for a display cell of the present invention.

An observer 2 is placed in front of the twisted nematic field effect mode liquid crystal display cell, which comprises a front polarizer 3, an optical fiber plate 4, a front transparent electrode 5, a front orientation layer 6, a liquid crystal layer 7, a seal member 8, a rear orientation layer 9, a rear transparent electrode 10, a rear glass substrate 11, a rear polarizer 12, and a reflector 13.

Figure 4 shows, more specifically, the optical fiber plate 4. Like elements corresponding to those of Figure 3 are indicated by like numerals.

The optical fiber plate 4 comprises a plurality of optical fibers of which axes are perpendicular to the layer plane of the liquid crystal layer 7, and has an internal surface 14 which is substantially parallel with the layer plane of the liquid crystal layer 7.

Each optical fiber has a length l, which is sufficiently longer than a radius r thereof, thereby uniforming the viewing angle dependency. The internal surface 14 of the fiber plate 4 is spaced from the liquid crystal layer 7 by a distance m, which corresponds to the thickness of the front transparent electrode 5 and the front orientation layer 6, and which is preferably selected below 40r. If the distance m is greater than 40r, an image can not be observed through the fiber plate 4.

The above-discussed twisted nematic field effect mode liquid crystal display cell, which is proposed in the copending application No. 7842412, is effective to uniform the viewing angle dependency. However, on the other hand, the brightness of the display is reduced if the open end of each optical fiber has a small size. And, if the open end of each optical fiber has a large size there is a possibility that one optical fiber extends over the activated picture element and the non-activated picture element, whereby the display contrast is deteriorated.

Figure 5 shows the relationship between the optical fibers and picture elements in the twisted nematic field effect mode liquid crystal display cell of Figure 3. In the cell of Figure 5, the electrodes 5 and and 10 are formed in a matrix fashion to achieve the matrix type display.

More specifically, the front transparent electrode 5 is a parallel X-line electrode made of In_2O_3, and the rear transparent electrode 10 is a parallel Y-line electrode perpendicular to the X-line electrode and made of In_2O_3. The crossing points of the X-line electrodes and the Y-line electrodes function as picture elements 5'. Each optical fiber comprises a core section and a clad section. In Figure 5, 4' represents the open end configuration of the core section, and 4'' represents the clad section. The front and rear orientation layers 6 and 9 comprise rubbed SiO_2 layers of around 1000Å thickness or SiO layers formed through the use of the titled evaporation technique. The liquid crystal layer 7 comprises the cholesteric liquid crystal showing the positive dielectric anisotropy and having a long pitch, or the nematic liquid crystal. A preferred composition is, for example, "E—8" manufactured by BDH Chemicals Ltd., or "ROTN 403" manufactured by F. Hoffman-La Roche & Co. In the case of the transmission type display, a light source is positioned at the back of the rear polarizer 12 instead of the reflector 13.

Figures 6(A) and 6(B) show undesirable relationship between the core open end 4' and the picture element 5'. If only a portion of one core open end 4' extends over a portion of one picture element 5' as shown in Figure 6(A), the display contrast is deteriorated. If the core open end 4' has a size considerably smaller than the picture element 5' as shown in Figure 6(B), the brightness of the display is reduced.

To eliminate the above-mentioned defects, in accordance with the present invention, the fiber plate 4 is constructed so that the core open end 4' substantially corresponds to the picture elements 5' as shown in Figures 7(A) and 7(B). In this way, the display contrast and the display brightness are greatly enhanced.

In the case where the core open end 4' has a considerably large size, it is preferable that a reinforcing plate 14 is interposed between the optical fiber plate 4 and the front transparent electrode 5 as shown in Figure 8. The reinforcing plate 14 must be transparent and show the optically isotropic characteristic. The front polarizer 3 can be positioned between the optical

fiber plate 4 and the reinforcing plate 14. In this case, the reinforcing plate 14 must be as thin as possible to ensure the clean display, and have the thickness substantially identical with the diameter of the edge of the core open end 4' at the maximum. In another preferred form, another reinforcing plate can be disposed between the front polarizer 3 and the optical fiber plate 4. The reinforcing plate must be transparent and show the optically isotropic characteristic, and is preferably made of glass.

Although the above-mentioned embodiment relates to the liquid crystal display of the matrix type, the present invention is applicable to the liquid crystal display of the segment type. Figure 9 shows a preferred relationship between the segmented picture element 5' and the core open ends 4' in the liquid crystal display of the segment type.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications are intended to be included within the scope of the following claims.

Claims

1. A twisted nematic field effect mode liquid crystal display cell comprising:
a front transparent substrate;
a front polarizer;
a rear substrate;
a liquid crystal layer disposed between said front transparent substrate and said rear substrate;
a front transparent electrode formed on said front transparent substrate; and
a rear electrode formed on said rear substrate, said front transparent electrode and said rear electrode defining, in combination, a picture element for display purposes said front transparent substrate comprising:
an optical fiber plate including a plurality of optical fibers of which axes are substantially perpendicular to the plane of said liquid crystal layer, each optical fiber having an open end confronting said liquid crystal layer and having a core open end of a configuration substantially corresponding to said picture element defined by said front transparent electrode and said rear electrode.

2. The twisted nematic field effect mode liquid crystal display cell of claim 1, wherein said optical fiber plate has a surface confronting said liquid crystal layer, said surface being substantially parallel with said plane of said liquid crystal layer.

3. The twisted nematic field effect mode liquid crystal display cell of claim 2, further comprising a reinforcing plate interposed between said optical fiber plate and said front transparent electrode.

4. The twisted nematic field effect mode liquid crystal display cell of claim 1, 2 or 3, wherein said front transparent electrode comprises a plurality of line electrodes; and said rear electrode comprises a plurality of line electrodes transversely formed with respect to said transparent electrode, thereby determining matrix shaped picture elements.

5. The twisted nematic field effect mode liquid crystal display cell of claim 1, 2 or 3, wherein at least one of said front transparent electrode and said rear electrode is segment shaped to achieve the segment type display, and wherein said optical fiber plate comprises at least two optical fibers which, in combination, substantially correspond to the configuration of said segment shaped electrode.

6. A twisted nematic field effect mode liquid crystal display cell, having an optical fiber plate disposed in front of a liquid crystal layer of the cell, the plate comprising optical fibers having axes perpendicular to the plane of the liquid crystal layer, wherein the cell has a display element which substantially corresponds in size, location and configuration to the end of a fiber, or the ends of a group of fibers, confronting the liquid crystal layer.

7. A liquid crystal display cell substantially as herein described with reference to Figures 3 to 5, as modified by Figure 7(A), 7(B), 8 or 9 of the accompanying drawings.

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